CLAIMS

1. A semiconductor device comprising an insulating film, the insulating film being formed of an insulative inorganic material as a main material, the insulative inorganic material containing silicon and at least one kind of element other than silicon, and the insulating film containing hydrogen atoms, wherein the absorbance of infrared radiation of which wave number is in the range of 3200 to 3500 cm^{-1} is 0.02 or less when the insulating film to which an electric field has never been applied is measured with Fourier Transform Infrared Spectroscopy at room temperature.

2. The semiconductor device as claimed in claim 1, wherein the insulating film includes a plurality of particular structures of atomic groups each of which is constructed from hydrogen and the at least one kind of element other than silicon and in which a hydrogen atom is bonded to an atom of the at least one kind of element other than silicon, wherein the absorption of the infrared radiation having the wave number within the range is derived from the plurality of particular structures of the atomic groups.

3. The semiconductor device as claimed in claim 1, wherein the at least one kind of element other than silicon includes oxygen.

4. The semiconductor device as claimed in claim 3, wherein the at least one kind of element other than silicon further includes at least one of nitrogen, hafnium, zirconium, and aluminum in addition to oxygen.

5. The semiconductor device as claimed in claim 1, wherein each hydrogen atom in at least a part of the hydrogen atoms is replaced by a deuterium atom.

6. The semiconductor device as claimed in claim 1, wherein the average thickness of the insulating film is 10 nm or less.

7. The semiconductor device as claimed in claim 1, wherein the semiconductor device includes a gate electrode and a gate insulating film for insulating the gate electrode, and the gate insulating film is formed from the insulating film.

8. The semiconductor device as claimed in claim 7, wherein the semiconductor device is adapted to be used under the condition that a gate voltage is applied to the gate electrode so that the electric field intensity in the insulating film is 10 MV/cm or less.

9. The semiconductor device as claimed in claim 7, wherein a leakage current passing through the gate insulating film in the thickness direction thereof that is measured in a state that the gate voltage is applied to the gate electrode so that the electric field intensity in the insulating film is 5 MV/cm or less is 9×10^{-9} A/cm^2 or less.

10. The semiconductor device as claimed in claim 7, wherein the total amount of electrical charges passing through the gate insulating film in the thickness direction thereof until a soft breakdown occurs in the insulating film is 40 C/cm^2 or more.

11. The semiconductor device as claimed in claim 7, wherein the total amount of electrical charges passing through the gate insulating film in the thickness direction thereof until a hard breakdown occurs in the insulating film is 100 C/cm^2 or more.

12. The semiconductor device as claimed in claim 1, wherein the Fourier Transform Infrared Spectroscopy is Multi-Reflection Attenuated Total Reflection Method.

13. An electronic device comprising the semiconductor device defined by claim 1.

14. An electronic apparatus comprising the electronic device defined by claim 13.

AMENDED CLAIMS

[received by the International Bureau on 27 April 2005 (27.04.2005);
original claims 1, 4, 5 and 8-11 amended; original claims 2, 3, 6, 7 and 12 cancelled;
remaining claims unchanged (3 pages)]

1. (Currently Amended) A semiconductor device comprising:

a gate electrode; and

a gate insulating film for insulating the gate electrode, the gate insulating film being formed of an insulative inorganic material as a main material, the insulative inorganic material containing silicon and oxygen, the insulating film containing hydrogen atoms, and the gate insulating film including Si-O(H)-Si structures therein;

wherein the average thickness of the gate insulating film is 10 nm or less, and the absorbance of infrared radiation of which wave number is in the range of 3200 to 3500 cm^{-1}, which is derived from an OH structure of any of the Si-O(H)-Si structures existing in the gate insulating film, is 0.02 or less when the gate insulating film to which an electric field has never been applied is measured with a Multi-Reflection Attenuated Total Reflection Method at room temperature.

2. (Deleted)

3. (Deleted)

4. (Currently Amended) The semiconductor device as claimed in claim 1, wherein the insulative inorganic material further includes at least one of nitrogen, hafnium, zirconium, and aluminum in addition to oxygen.

5. (Currently Amended) The semiconductor device as claimed in claim 1, wherein each hydrogen atom in at least a part of the

hydrogen atoms is replaced by a deuterium atom.

6. (Deleted)

7. (Deleted)

8. (Currently Amended) The semiconductor device as claimed in claim 1, wherein the semiconductor device is adapted to be used under the condition that a gate voltage is applied to the gate electrode so that the electric field intensity in the insulating film is 10 MV/cm or less.

9. (Currently Amended) The semiconductor device as claimed in claim 1, wherein a leakage current passing through the gate insulating film in the thickness direction thereof that is measured in a state that a gate voltage is applied to the gate electrode so that the electric field intensity in the insulating film is 5 MV/cm or less is 9×10^{-9} A/cm^2 or less.

10. (Currently Amended) The semiconductor device as claimed in claim 1, wherein the total amount of electrical charges passing through the gate insulating film in the thickness direction thereof until a soft breakdown occurs in the insulating film is 40 C/cm^2 or more.

11. (Currently Amended) The semiconductor device as claimed in claim 1, wherein the total amount of electrical charges passing through the gate insulating film in the thickness direction thereof until a hard breakdown occurs in the insulating film is 100 C/cm^2 or more.

12. (Deleted)

13. (Original) An electronic device comprising the semiconductor device defined by claim 1.

14. (Original) An electronic apparatus comprising the electronic device defined by claim 13.

Brief Statement

Amended Claim 1 is directed to a semiconductor device including a gate electrode and a gate insulating film. Claim 1 is amended so as to include the limitation of the original claims 2, 3, 6, 7 and 12. For this reason, these original claims are deleted. In this regard, the language "a Si-O(H)-Si structure" in amended Claim 1 means "a Si-OH structure 34" as seen in FIG. 3.

FIG. 6A of the cited document D1 is a graph showing a hydrogen bond in silicon nitride film (i.e., LP-SiN film 31 functioning as a gate cap insulating film for capping a gate electrode like a passivation film), which is measured by a FT-IR. However, the FT-IR has lower sensitivity than a Multi-Reflection Attenuated Total Reflection Method in order to measure a thin film (for example, a film having an average thickness of 10 nm or less). In this regard, it is to be noted that the LP-SiN film 31 has a thickness of 150 nm or more as seen in FIG. 7 of the cited document D1. Therefore, there is an obvious difference between measuring objects of the present invention and the cited document D1. Namely, the gate insulating film of the present invention is a thin film having an average thickness of 10 nm or less (see amended Claim 1 of the present invention), while the LP-SiN film 31 of the cited document D1 is a thick film having an average thickness of 150 nm or more as described above.

Further, in the present invention, the absorbance of infrared radiation of which wave number is in the range of 3200 to 3500 cm^{-1} is derived from an OH structure of any of the Si-O(H)-Si structures existing in the gate insulating film. On the other hand, in the cited document D1, the absorbance of infrared radiation of which wave number is in the range of 3000 to 3500

cm^{-1} is derived from an N-H bonding existing in the LP-SiN film (i.e., gate cap insulating film).